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USAAVRADCOM TR 78-7

SPADE SENSOR LOCATION AND ATTACHMENT

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27 JANUARY 1978

FINAL REPORT

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PREPARED FOR

DIRECTORATE FOR DEVELOPMENT AND ENGINEERING
U. S. ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER (18) USAAVRADCOM (19) TR-78-7

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) (6) SPADE Sensor Location and Attachment.

5. TYPE OF REPORT & PERIOD COVERED (9) Final Report.

6. PERFORMING ORG. REPORT NUMBER (15)

7. AUTHOR(s) (10)
Timothy C. Mayer,
Harold W. Sutphin
J. Thomas Harrington

8. CONTRACT OR GRANT NUMBER(s)
BOA DAAJ01-77-A-0012 (P6C)
DO DAAJ01-77-A-0012-0001(P6C)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Parks College
St Louis University
Cahokia, IL 62206

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Directorate of Research & Development
US Army Aviation R&D Command
PO Box 209

12. REPORT DATE (11) 27 January 1978

13. NUMBER OF PAGES 14

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(12) 21p.

15. SECURITY CLASS. (of this report) UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Shock Pulse
Bearing
Helicopter
Drive Component
Diagnostic Equipment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report optimizes sensor locations for the shock pulse vibration technique, investigates the shock emission profile difference between using an IFD multi-model transducer using an epoxy mounting technique vs a B&K accelerometer using a collar and damp technique and finally the recommendation of candidate bearings for shock pulse monitoring on the UH-1H, AH-1G, OH-58C and the CH-47.

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409200

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The Shock Pulse technique works on the principle that a descrete fault, such as a pit or a spall, will cause repetitive impacts of short duration. These impacts will cause shock waves to propagate through the bearing structure causing a pulse displacement input to an accelerometer, suitably, attached to the bearing structure. The output of the accelerometer passes through a high gain amplifier tuned at the resonant frequency of the accelerometer (this amplifier then acts as a sharp band-pose filter). After the signal is processed the output is displayed on a counter which provides the frequency of peaks above any desired peak amplitudes.

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SPADE SENSOR LOCATION AND ATTACHMENT

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BOA DAAJ01-77-A-0012 (P6C)
DO DAAJ01-77-A-0012-0001 (P6C)

ACKNOWLEDGEMENT

The College appreciates the assistance of the 102nd USARFFAC, stationed at Scott Air Force Base, Illinois.

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1.0 INTRODUCTION

To satisfy a need for additional data collection and analysis with the shock pulse meter, Parks College was contracted to perform the following TASKS:

TASK 1:

(a) Collect shock pulse data and optimize sensor location for the shock pulse vibration technique.

(b) Investigate differences in shock emission profiles using the IFD multi-model transducer and an epoxy mounting technique plus the lower cost B&K accelerometers with the standard collar mounting technique.

This work was performed at Scott Air Force Base, Illinois.

TASK 2:

Recommend candidate bearings for shock pulse monitoring on the UH-1H, AH-1G, OH-58C and CH-47. These recommendations shall be based component failures data, flight safety and maintainability considerations, accessibility of sensor locations, and data collection verification (when test results are available).

2.0 COMPONENT SENSOR OPTIMIZATION

2.1 UH-1H

90° Gear Box

Two methods of data collection have been employed to collect data from the 90° gear box.

1. A clamp was attached to the studs holding the gear box halves together. Because of constraints of noninterference the clamps were not positioned in an optimized location during most of the previous data collection, however, testing has revealed the stud locations which serves to best interpret the gear box condition.
2. An effort has been employed to attach an accelerometer by an epoxy affixed stud mount which could be located to reduce both the distance and mechanical interfaces to the bearing assembly. The epoxy (dental adhesive) assembly proves reliable in data collection, however, no testing on implanted assemblies, or testing as to the assemblies' ability to stand up to environmental conditions common to normally anticipated operating areas, has been initiated. Since limited testing has been undertaken, further evaluations must be made before any endorsement can be forthcoming which would substantiate this method of collection.

42° Gear Box

This gear box is made up of two bearing assemblies (input and output); each is a separate unit although identical in the make-up of bearings within the assembly. Two accelerometers were used for the bulk of the previous test collection; one on the input quill assembly, the other on the output quill. Each accelerometer was mounted to the case studs which holds the quill in the gear box housing. As in the bulk of assemblies tested, the accelerometer was

mounted to a clamp affixed to collars slipped over studs and kept secure by the nuts which normally hold the quills into the case. This method of data collection has been successful in isolating implants in either quill assembly, however, two accelerometers were required to completely diagnose the assembly.

Limited testing has been undertaken utilizing epoxy mounted accelerometers discussed in the 90° gear box testing. Studies indicate a feasibility exists to reduce the present two accelerometers to one which is centrally located and still able to interpret either input or output quill. This capability has been preliminarily evaluated, however, as with the previously mentioned epoxy mounted sensors. A less than ideal number of tests have been made which would indicate the superiority of this type of data collection. Testing to date with epoxy mounted accelerometers has generally yielded higher values because of reduced attenuation due to a reduction of interfaces as well as better placement ability over the bearing assembly.

Hanger Bearing

Two hanger bearing assemblies have been evaluated (#3 and #4) during the bulk of data collection to date. The reason behind testing only the 3 and 4 bearing assembly was due to ease of attachment.

Number 1 and 2 assemblies are less than desirable due to cowling interferences. The possibility exists to evaluate either (#1 or #2) hanger bearings using the epoxy mounted accelerometers, although no attempt has yet been made to obtain data using that method. The feasibility exists to obtain data on any of the hanger bearing assemblies of any model of the UH-1 series using either clamps attaching directly to the lands of the bolts holding the hanger bearing fixture to the aircraft, or the clamp and collar method. As previously mentioned, the only difficulty encountered in obtaining data of

any hanger bearing assembly is with cowling interference in the area of the engine. A clamp can be made which would allow data to be collected. However, a consideration to permenantly mounting an accelerometer should be made in relation to cost effectiveness of such an installation on the forward assemblies.

Tail Rotor Output

A permanently mounted fixture was installed on the quill assembly of the tail rotor output drive on which an accelerometer was affixed. The reason data was collected from a permanently installed fixture was because of the difficulty in accelerometer attachment. Of special concern was the time element of man-hours required for each installation. Not only was the accelerometer mounted permanently to a fixture bolted to the output quill but the wiring for data collection was routed and installed so as to allow access from the outside of the transmission pylon area. Since an accelerometer and wiring is dedicated and in place even when data is not being collected consideration should be made as to the cost effectiveness of a permanently mounted accelerometer versus the probability of a damaged bearing being found which would bear on a critical safety of flight situation. Another consideration might be to allot a particular phase maintenance check, which would have the transmission pylon area exposed for data collection of the tail rotor output quill.

Input Drive Quill

The input drive quill to the transmission has been analyzed and data collection undertaken using both a clamp assembly directly on the quill mounting nuts and clamps mounting to stainless steel collars which fit over the quill mounting studs. Either of these methods of collection has yielded consistent data; although by using the collars the requirement to match the

clamp to the particular design nut is eliminated. Access to the input quill area is from the top of the transmission. No cowling interferences are present which would preclude quick data collection.

Mast Bearing

Data has been collected from the mast bearing by attaching the accelerometer to one of the studs which hold the bearing assembly to the upper mast section of the transmission. Both direct attachment to the securing nuts and attachment to the stainless collars have been used for collection. The data collected to date on the mast bearing has not proved to be reliable in detecting damaged components. Several methods have been employed to vary the bearing load, as well as change the direction of the transducer's path of shock collection, without success. The probability exists that because of the poor mechanical interface inherent in the location of mast bearing in relation to available data collection methods, a reliable method of data collection cannot be found for this assembly. We feel that since no significant material failure data exists which shows this assembly to be either prone to failure or having a history of damage which would go undetected by conventional inspection techniques, that further attempts to use shock pulse data collection be suspended.

Additional Transmission Studies

Three other areas of data collection were studied on the UH-1 series aircraft. They were: The upper, middle and lower flange mounts of the main transmission. The original purpose of data collection in these areas was to establish the feasibility of identifying implants of bearings within the transmission main body. A relatively few implants were made and thusly, it is not possible to accurately indicate a measure of success on these implants.

One area of interest lies in the apparent ability to detect implants in other assemblies (i.e.), the input drive quill, by the direct mechanical interface which exists in relation to the middle and lower flange-mounted accelerometers. A continued effort must be made to include further transmission implants before a finalized placement of accelerometers on the transmission main body can be made. The accelerometers were mounted by means of the clamp and collar method previously mentioned.

2.2 T53-L13 Engine

Several positions on the engine were used to collect data relevant to diagnosing the condition of the main bearing assemblies such as; (1) #3-4 bearing assembly, (2) top of the engine (lift lug), (3) front side of compressor in the area of the #1 bearing, and (4) #2 bearing area. Due to the inherent inability to obtain a clear mechanical interface to the engine bearing assemblies in all positions except the #3-4 bearing area, we would suggest only a limited amount of data be collected from the engine. The #3-4 bearing assembly has a good interface by way of an oil scavenger line which is internally routed from the bearing assembly down at the aft portion of the engine. The accelerometer was attached to the scavenger by a fixture positioned at the existing pad used for vibration monitoring. This attachment procedure has provided for reliable and consistent data collection which has been successful in detecting implanted degraded #3-4 bearings.

All engine data collection was accomplished using a Modular Engine Test Stand (METS) either at Ft. Rucker, Alabama, or at Granite City Army Depot. Since access to engine components was of no concern using the METS facility, the same techniques for accelerometer attachment could not be used during field testing. The #3-4 bearing assembly could, however, be monitored using similar

pad mounts with the only constraint being the over-all length of the transducer which will be used in the finalized productions unit. An accelerometer which is too long would have to be specially mounted because of interference with the shrowd covering the tail rotor drive shaft as it is situated directly beneath the combustor and tail pipe area of the engine. Since we feel the continued collection of data from this engine area would be of value, an effort should be made to ensure the finalized accelerometer harness be designed to accomplish this end.

2.3 AH-1S And TH-1G

The same general areas of data collection were studied on these helicopters as the UH-1 because of a similarity in components and drive train design. No implant testing was undertaken and thusly, no definite conclusions can be made as to over-all effectiveness, however, on those components which are identical to the UH-1 we feel comparable success can be expected. All collection was made by mounting the accelerometers via clamps which fit over the lands of nuts which secured the components within the assemblies. The reason behind this type of attachment was that all testing was of a noninterference nature and access to the aircraft made only on an occasional basis. Data was monitored on the #2 hanger bearing of the TH-1G because of the availability of mounting a sensor without interference with aircraft components. The only other area which represents shock pulse data on an other-than-standard assembly was the 90° gear box of the TH-1G. Shock pulse signatures were collected from both the input and output of this assembly. However, since no testing was made on components of known condition, it is not possible to establish exact baseline criteria or definite threshold limits which would relate to the shock level.

2.4 OH-58

Several areas of data collection were explored on the OH-58 type of helicopter. A shock pulse collection was affected on operational helicopters at Ft. Rucker, Alabama. No implant testing was made, therefore, data collected cannot be correlated with known assembly condition. Because correlation was not possible, it follows that an analysis of the success in isolating damaged components cannot be made. Thusly, no recommendations as to accelerometer placement can be forthcoming. All data collected on the OH-58 was by collars attached to the lands of attachment nuts at each assembly. The following list of components represents areas in which shock pulse signatures have been acquired:

- 90^o Gear Box Output
- 90^o Gear Box input
- Hanger Bearings #2, 3, 5, 6, 7, 8
- Planetary Support Bearing
- Transmission Mast Bearing
- Input Drive Quill

Although the feasibility exists to monitor other positions, constraints on noninterference precluded a more extensive analysis of the drive train components.

2.5 CH-47

Three models of the CH-47 helicopter were analyzed: CH-47B, C and Super C. A very limited number of collection runs were made on each model and, as with the OH-58 test series, no implant or comparison with known condition assemblies were made. The main criteria used in selecting components to be monitored was accessibility and ease of transducer attachment. Accelerometer

attachment was made via both clamp and collar, where such installations could be effective and by clamping directly to the lands of attaching nuts. No definite statement can be made as to success of any attachment position because, as previously mentioned, controlled conditions of known assemblies were not made. The following list represents the components which data was collected from:

#1 Input Combining Transmission

Input Combining Transmission (Bottom)

Aft Output Combining Transmission

Forward Output Combining Transmission

#2 Sync. Shaft Support Bearing

Input Drive Quill (Forward Transmission)

Swash Plate Bearing

#1 Engine 90^{o} Gear Box

Input to Combining Transmission

Sync. Shaft Support Bearing (Rear Bottom)

Forward Gear Box Input

Oil Pump

#2 Engine Input to Combining Transmission (Outboard)

3.0 Transducer Comparison

To satisfy a need to show the differences in shock emission utilizing the IFD multi-model transducer versus lower cost B&K transducer, an investigation was undertaken. The 42^{o} gear box was utilized as a component to test these transducers, specifically a clamp and collar on the output side of the gear box. The 42^{o} gear box is not new, having runtime on it, but is considered in a clean configuration, i.e., no implanted bearings or gears. The 4th Run in Figure 1 shows levels obtained from three transducers used on a

single run. The Endevco transducer normally used (and also used at Fort Rucker), gave a level of 300 as did the newer B&K transducer. The curves that were plotted were also nearly identical. The Endevco multi-model transducer yielded a lower level of 200 and a slightly higher rate. During the course of plotting data a needle swing was also noted through the knee of the curve making plotting difficult. This occurred only with the Endevco multi-model transducer and not the B&K , or normally used Endevco.

4.0 Epoxy Mounting Technique

An "epoxy" mounting technique was utilized to also examine differences in shock emission with respect to the clamp and collar technique. The components utilized were the 90° gear box, 42° gear box and the #4 hanger bearing assembly. The hanger bearing used had damage progressing within it.

The "epoxy" mount consisted of a small machined aluminum pad (as shown in Figure 2) being adhered to the component with a strong dental cement. It was adhered over the area that was thought to have an optimum mechanical interface to the bearing assemblies. Those locations are shown in Figures 3-5. A location was also tested on the 42° gear box that cannot be directly compared to data from a similar clamp location; its placement being the center of the gear box as shown. Another type of pad mount was utilized which consisted of a stainless steel rod approximately 1/2 inch in diameter and 1/2 inch long with a 10-32 thread tapped into one end for transducer mounting. It was felt that the mass of this particular pad attenuated the signal and thus precluded obtaining good shock emission data.

In order to obtain a strong bond with the dental adhesive, the locations were sanded to bare metal and cleaned chemically. The adhesive was mixed and applied to the pad which in turn was affixed to the component.

Drying time was relatively quick and the transducers could be torqued to the normally used value of 15-inch pounds. No failures of the adhesives occurred during any of the ground runs of the aircraft.

As was stated previously, the initial epoxy runs generally yielded higher levels. In the 1st and 2nd Runs of the #4 hanger bearing assembly (Figure 1), the levels obtained with the epoxy mounted accelerometer were 800 and 1000 respectively. The levels obtained in the same two runs with the clamp and collar mount were 650 and 600 respectively. It was felt that the mechanical interface was better than with the normally utilized clamp and collar and would account for differences in levels obtained.

Data utilized for the clamp mount (1st Run, Figure 1), on the 42° input, 42° output and 90° gear box (1st and 2nd Run) are averaged from all previous runs for these particular components. The data obtained from the epoxy mount of the same components are nearly identical.

In the (3rd Run, Figure 1), a 42° gear box with damaged gears and bearing implant MAIC 003 installed in the input quill, was used. The spall on the inner race of the -1 bearing was only partially in the ball path. The input and output mounted pads yielded levels lower than those of the clamp mounts, while the centrally located pad had the highest level. It was felt that since the location of the pad provided optimum mechanical interface to the roller bearing on the input quill, any progressing damage yielding particulate matter would show a high level as a result.

Since testing was limited, further evaluation must be made before any endorsement can be made to substantiate this method of data collection.

5.0 FIGURES

Component	1st Run		2nd Run		3rd Run		4th Run	
#4 Hanger Bearing	650	800	600	1000	-	-	-	-
42° Gear Box Input	925*	800	-	-	1250	500	700	900
42° Gear Box Output	400*	350	400	-	1500	400	(A) 300 (B) 200 (C) 300	325
42° Center	**	700	**	400	**	3000	**	600
90° Gear Box	100*	125	100*	100	-	-	-	-
	Clamp	Epoxy	Clamp	Epoxy	Clamp	Epoxy	Clamp	Epoxy

Figure 1

*Average Of Data For This Component
**No Clamp Position Available

(A) Normal Accelerometer
(B) Endevco Multi-Model Accelerometer (New)
(C) B&K Accelerometer (New)

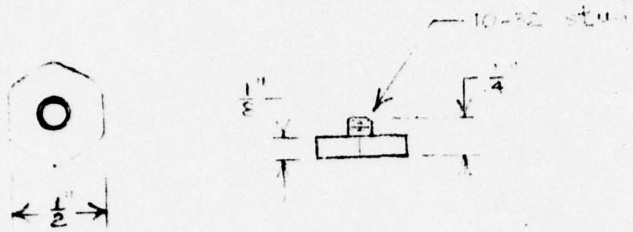

Figure 2

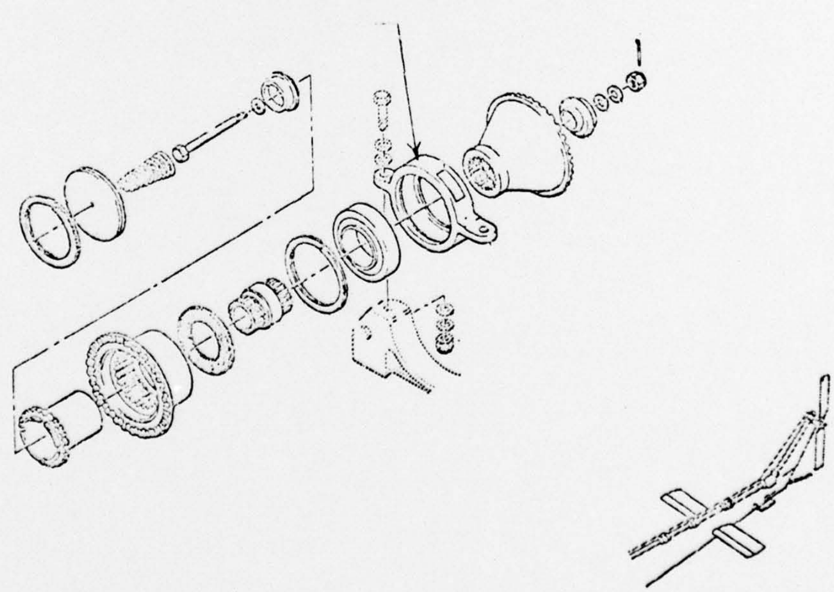

Figure 3

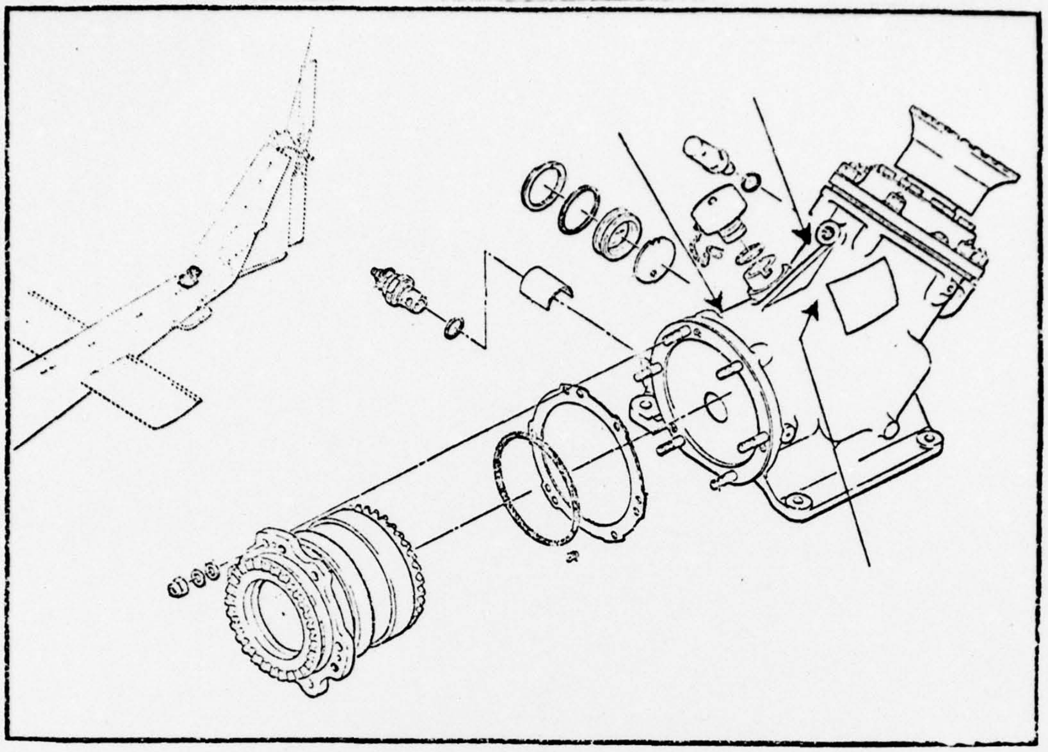

Figure 4

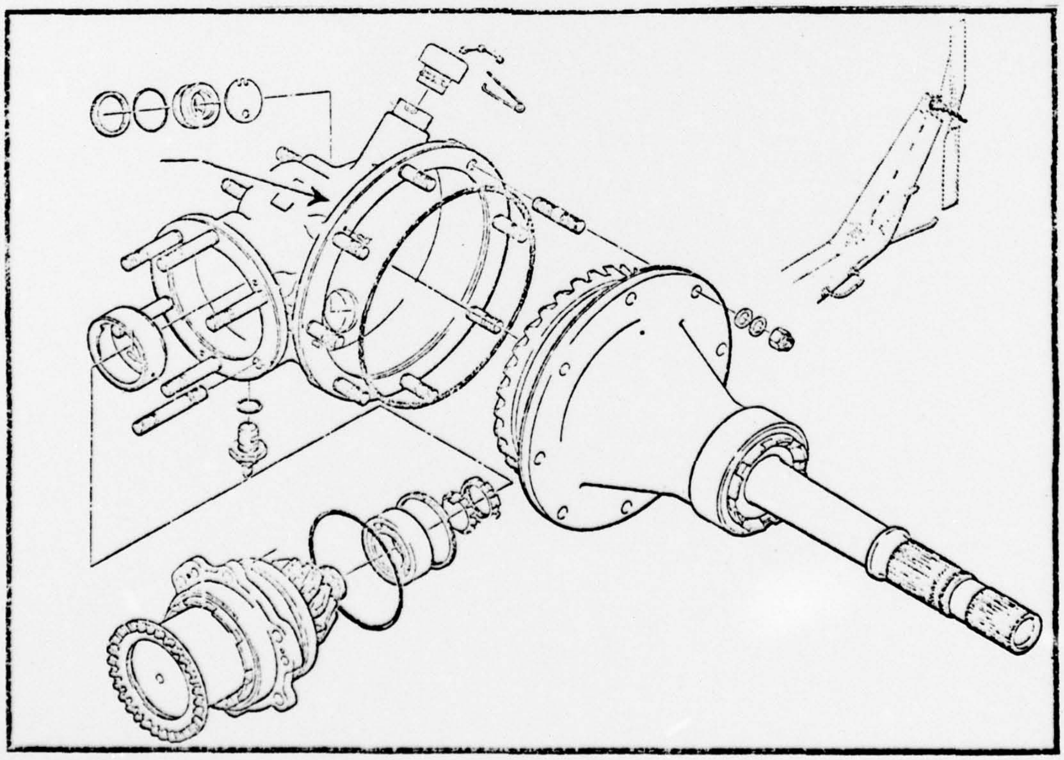

Figure 5